BEHAVIOR OF MINERAL MATTER DURING COAL BENEFICIATION

Harold L. Lovell

The Pennsylvania State University
Department of Mineral Engineering
University Park, Pennsylvania 16802

Each coal beneficiation unit operation responds to the physical and chemical properties of its feed. The response is as a "collage" of the individual particles but specifically as the frequency distribution of the component particle properties. These particle responses are not totally independent with particle property-process parameter interactions, but are also significantly controlled by the overall distribution of particle properties. Diligence is appropriately applied to establish the "collage" distribution by certain particle properties of the plant feed. This distribution provides the design bases for each unit operation in the flow sheet - including its capacity, flow rate, and unit loading: thus ultimately defining the separational performance, efficiency, and unit costs. Each unit operation should be sized and operated such that its optimum performance is well within the sensitivity range of its feed property distribution. The concern that the feed distributions may, at times, exceed the sensitivity range for some unit operation within in the system, is normally related to in situ coal variability, which can be extreme. The concern may extend to coal feeds from differ -rent seams and/or paleo-geological origin, mining system, or handling-storage system. Unfortunately, seldom are the concerns extensive and rarely are the feed characterizations detailed to each down stream operation.

The plant feed characterization usually is limited to particle size distribution and, if detailed, will include a particle gravity distribution for several size groupings greater than 28 or 16 mesh (washability). There is no generally accepted range for either the size or density groupings. The characterization of the individual particle fractions are usually limited to moisture, high temperature ash, and total sulfur content. In some unusal instances the low temperature ash and sulfide sulfur content may be determined. Pragmatism, procedures, and economics prevent the direct determination of minerals whose concentrations will be modified in the process. These levels are expressed in terms of ash content. If there is any characterization of the individual macerals or minerals, they are evaluated on the basis of the "total-composite" feed sample. Should flotation processes be anticipated, some "laboratory floatability" studies (1), may be carried out on some minus 16 or 28 mesh or other sized fraction. The origin of the particular fraction thus tested, seldom relates to that which will exist within the plant flow sheet. Feed hardness or friability tests (as Hardgrove Grindability Index, Drop-Shatter, etc.) may also be determined on the composite feed sample. If any comminution evaluations are made for the particular feed coal in the course of selecting a particular comminution device, they are usually made on a sample purported to be representative of the plant feed. Attempts to evaluate variations of particle strength or stability, maceral, mineral, or elemental composition, have been limited to research characterizations, as those reported by the author (2). We are almost totally devoid of pragmatic techniques to establish the particle sizes or volumes of individual components within a given individual coal particle (Richardson and Lovell (3).

These observations can but lead to the conclusion that, in contrast, to typical unit operations in chemical engineering, the coal processing engineer assumes a feed to each unit operation within the plant system based upon the defined plant feed. Further, it is assumed that the collage of particles entering the plant as feed DOES NOT CHANGE in passing through the processing system and that the same number of particles 2 by 1-inch having densities between 1.40 and 1.45 gm/cc (or any other fraction) leaves the plant as enters! We know that this is not correct even if we ignore the comminution operations within the plant designed to make such changes!

The composition of any individual coal beneficiation feed particle ranges from a nearly uniform metamorphized, phyto component through an almost infinite mixture series with macerals-minerals to an opposite end member as a nearly uniform mineral component. The behavior of a beneficiation feed during processing is determined by this almost limitless (and changing) distribution of individual particle compositions whose responses to process parameters are established by the particle properties as size, shape, density, hardness, porosity, and gas-liquid-solid interfaces. The particle responses establishes its direction and rate of movement toward one of the process product ports.

With coals as sedimentary rocks of paleophyto origin, their inorganic contents incorporate those components which were part of the original phyto system and associated substances, as well as those that have been introduced through all the subsequent geologic events. Accordingly, the mineral components found in coals reflect the nature of the originating plant systems, their environment, degree of water existing (whether of fresh or marine water character), oxidation-reduction conditions, temperatures, and pressures as well as those conditions to which the coal-forming strata have been subject during all the ensuing geologic epochs, including past and current circulating ground waters. Thus the observed complexity of the resulting physical characteristics is to be expected.

The minerals found in United States coals continue to be studied with the availability of improved instrumental procedures as X-ray diffraction, infrared absorption, and scanning electron microscopy beyond the traditional optical and chemical mineralogical techniques as applied to thin sections, polished pellets, and isolated particles. The minerals may be grouped into <u>the silicates</u> (kaolinite, illite, monmorillonite, and chlorite); <u>the oxides</u> (quartz, chalcedony, hematite); <u>the sulfides</u> (pyrite, marcasite, and sphalerite); <u>the sulfates</u> (jarosite, gypsum, barite, and numerous iron sulfate minerals); <u>the carbonates</u> (ankerite, calcite, dolomite, and siderite); and numerous <u>accessory minerals</u> as apatite, phosphorite, zircon, rutile, chlorides, nitrates, and trace minerals).

The greatest interest in mineral occurrences in coal particles for processing engineers relates to their potential liberation as an essential first step for their physical removal. Further the concern relates to the mineral behavoir in each of the unit operations within the preparation plant and environmental implications within the preparation operations, for utilization of the clean coal product and the disposal of the refuse materials. The greatest attention has been given to the former interests, especially as applied to the liberation of pyrite in efforts to achieve the greatest possible sulfur reduction during processing.

Specific Responses of Coal Mineral Components During Processing

The "collage " of particles entering a coal processing plant are subject to a series of unit operations designed to achieve the desired level of quality improvement. The development of the initial set of particles is determined by the mining and preprocessing storage and handling systems. Undoubtedly these operations introduces stresses within the coal particles that lead to subsequent fracture failures. Any potential control of the nature of this particle set is usually extremely limited - being determined by production and economic factors. Situations which lead to oxdiation, decripitation, and absorption of excessive levels of moisture may be modified. The introduction of moisture prior to processing probably enhances clay swelling, tends to increase the amount of mineral fines (usually clays) into the plant stream, and may enhance localized heating, swelling, and oxidation. Initiation of dispersion of clays may begin here. Uncontrolled comminution during the handling and storage due to dropping from stackers, compaction by graders, etc. tend to create fines and probably selectively favors reduction of the softer particles, especially certain clays. Other handling steps as particle movement through pumps, jigs, etc. tend to accent the production of fines. The oxidation of coal and temperature increases may favor the production of water soluble salts leading to acid plant waters and potential corrosion.

Primary crushing which usually involves breakers or single roll crushers may be preceeded by a scalping operation to remove large particles of hard shales and sandstones. Such operations though not rejecting large amounts of refuse, do prevent wear, save energy, and prevent the introduction of additional refuse fines into the plant feed. The primary comminution devices usually are designed to control top size rather than achieve particle liberation, as such, they offer an opportunity to minimize fines production and show some selectivity toward the large, harder particles as shales and sandstones. Pre operational testing of comminution devices should consider the production of minimal amount of mineral fines. In coal processing systems where classifying rotating mills may be used, the selective build up of harder components within the mill can affect system performance.

In coarse coal sorting operations, as jigs and heavy media vessels, the softer minerals will tend to comminute due to attritional actions of particle movements and result in further dispersion into the plant circulating water system. In jigs, the production of mineral fines may be desirable to enhance hindered settling effects. In the Haldex heavy media system (4) and water only cyclones, the presence of mineral fines are essential to serve as an autogeneous heavy media system. Operational care must be taken to prevent the build up of unacceptable levels of fines leading to unacceptable fluid viscosity levels. Although quartz, clays, and other very fine mineral particles enhance these conditions, several type of clays, notably kaolinite and montmorillonite (especially sodium), are especially responsive. Suspended clay levels above five percent in such systems are most undesirable and may limit control of density in magnetite heavy media systems. The viscosity effect increases with decreasing particle size and with spherical shape which enhances settling rates. These concerns can also become critical in coal-water transport systems.

In fine coal sorting systems, heavy media cyclones, water only cyclones, tables and spirals the density and viscosity responses of suspensions are even more critical. In froth fltoation the presence of clay fines is undesirable and usually require a desliming step ahead of flotation if their concentration becomes excessive.

It is in the water circuit that the build up of fines, especially clays must be controlled. The responses become evident in dewatering devices as centrifuges and filters. In the latter case, clays may enhance blinding resulting in unacceptable water contents of the filter cake, thin watery cakes, and unacceptable performance. Difficulties in the filtration of refuse fines has lead recently to the introduction of expensive processes as pressure and belt filters to meet environmental standards. In thickeners, excessive clay fines may reduce settling rates, minimize the formation of desirable underflow slurry densities, and lead to plant failure. It is in the dewatering stages and water circuit, as processes at the end of the flow sheet that these responses become acute. Although the use of one or more polymeric flocculants can usually control these situations, unexpected changes in plant feeds may require feed rate reductions or plant shut down.

Recent environmental regulations which essentially require closed water circuits make the problems of mineral fines buildup especially severe. Similar difficulties are associated with the disposal of refuse fines.

These examples describe some of the more prominent responses of mineral components in coal processing operations. Control of these problems can be achieved with better detection and analytical systems to identify the problems.

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